

**FINAL REPORT , NAG5-816, Covering 7/15/86 - 6/30/93**  
Principal Investigator: Dr. R.E.Stencel, University of Colorado at Boulder

**IUE Guest Observer Approved Projects, to date:**

CSMRS (1990): Mapping UV Circumstellar Nebulae of Cool Stars  
ZAMRS (1990): ROSAT-IUE Coordinated Observations of Symbiotic Binaries  
CMKRS (1988): Mapping the Circumstellar Shells of Red Supergiants  
OD45Y (1987): Maximum Light Observations of the Red Supergiant Maser Source S Persei (M3 Iac)  
CSJRS (1987): The Ultraviolet Circumstellar Shell of  $\alpha$  Orionis  
MLJRS (1987): UV Observations of the Peculiar Red Giant HR 3126  
OD38Y (1986): IUE LWP Camera Scattered Light Measurements  
OD35Y (1986): VY Canis Majoris Near Maximum Light  
OD14Y (1986): Test Offset Observations near  $\alpha$  Orionis  
IUEIX (1986): Fundamental Properties of the EG Andromedae System Derived from High Dispersion Spectra at Opposite Quadratures

**PROGRESS DURING THE MOST RECENT SIX MONTHS AND SUMMARY:**

The expiration of this grant closes a productive chapter in a very productive relation between the PI and the NASA International Ultraviolet Explorer [IUE] program which predates this grant by an additional 7 years (1979). For the 8 years and \$91k of support provided under this grant, we have 17 publications to show for the effort, plus numerous pieces of work still in progress. The major observations of this period were the offsource experiments, which were innovative and still challenge interpretation. Separate funded analysis may have to proceed under archival programs as time and talent permit revisiting. By way of closure, the EG And studies begun with this grant have culminated in HST/GHRS spectra obtained in February 1993.

This grant went into one-year, no cost extension status as of 7/1/92. The residual funds were used to support final analysis on data obtained under programs listed above. Much of the work has been published in at least preliminary form in refereed papers or conference proceedings, but some work remains on the most recent data, including:

***IUE Scattered Light analysis***

Analysis of the scattered light observations obtained under IUE observing programs CSMRS and CMKRS has proven quite a challenge to fully interpret. Part of the problem lies in the limited signal to noise possible with IUE and the lack of adequate software analysis tools for the highly non-standard data derived from off-source observing. The recent (1992) development of high levels of FES scattered light compromises the possibility of obtaining any additional followup data, and therefore, these archives are unique and their worth explained in a suitable publication. Thus far, despite the problems, we have demonstrated the general shape of the IUE scattered light profile within about 20 arcseconds of the LWLA, and discovered excess scattered light within this region in the mass-losing red supergiant Betelgeuse (see papers 5 and 10). I still hope to complete a full report on these spectra.

***IUE ROSAT coordinated observations***

As discussed in previous status reports, IUE observations of selected X-ray symbiotic binaries were made during the second half of 1990 in coordination with ROSAT X-ray observations. IUE observations have been reduced, but the analysis has been on hold for availability of ROSAT results from the German collaborators. Reprocessing of the ROSAT all-sky survey data has been

delayed by calibration, staffing and hardware problems driven by supporting real-time observations. When real-time operations end in 1994/5, attention will return to the ROSAT survey archives.

#### PUBLICATIONS CITING SUPPORT OF NAG5-816:

1. "Symbiotic Stars" H. Nussbaumer and R. Stencel (invited chapter) 1987 in *The Universe at Ultraviolet Wavelengths*, eds. Y. Kondo and C. deJager (Dordrecht; Reidel), pp. 203-222.
2. "The Search for the Elusive Companion of EG Andromedae" J. Pesce, R. Stencel and N. Oliverson 1987 *Publ. Astron. Soc. Pacific* **99**, 1178.
3. "Diffraction Spikes and Faint Target/Bright Neighbor Observing" K. Carpenter, R. Stencel, J. Pesce, A. Brown, P. Judge and C. Jordan 1987 *NASA IUE Newsletter* **33**, pp. 20-24.
4. "SiO Cooling Instability in the Envelopes of Cool Giant Stars" D. Muchmore, J. Nuth and R. Stencel 1987 *Astrophysical Journal* **315**, L141.
5. "Direct UV Observations of the Circumstellar Envelope of  $\alpha$  Ori" R. Stencel, K. Carpenter, J. Pesce, S. Skinner, A. Brown and P. Judge 1988 in *A Decade of UV Astronomy: A Celebratory Symposium*, ed. E. Rolfe, ESA Spec. Publ. **281**, p. 249.
6. "Multiwavelength Observations of the Peculiar Red Giant HR 3126" J. Pesce, R. Stencel, J. Doggett, F. Walter, J. Dachs, P. Whitelock and R. Mundt 1988 in *A Decade of UV Astronomy: A Celebratory Symposium*, ed. E. Rolfe, ESA Spec. Publ. **281**, p. 253.
7. "The Production of Low Mass Carbon Stars: Carbon Dredge Up vs. Oxygen Mass Loss." R. Stencel, J. Pesce and K. MacGregor 1989 Proceedings of the IAU Colloquium (106): "Evolution of Peculiar Red Giant Stars", eds. H.R. Johnson and B. Zuckerman, Cambridge Univ. Press, p. 229.
8. "Line Identifications in the Ultraviolet Spectrum of 31 Cygni" W. Bauer and R. Stencel 1989 *Astrophys. Journal Supplement Series* Vol. **69**, pp. 667-700.
9. "The Evolution of Chromospheres and Winds of Red Giant Stars" P. Judge and R. Stencel 1991 *Astrophysical Journal* **371**, 359. Also summarized in *Sixth Cool Stars Workshop*, 1990, ed. G. Wallerstein, ASP Conf. Series Vol. **9**, pp. 411-413.
10. "Mapping the UV Circumstellar Shells of Red Giant and Supergiant Stars" R. Stencel, P. Judge and K. Carpenter

1990, in *Sixth Cool Stars Workshop*,  
ed. G.Wallerstein, ASP Conf. Series Vol. 9, pp. 467-470.

11. "Twelve Years of IUE Spectra of the Interacting Binary VV Cep"  
W. Bauer, R. Stencel and D. Neff  
1991 Astron. Astrophys. Suppl. 90, pp. 175-190.
12. "On the Nature of the Symbiotic Star CI Cygni"  
S. Kenyon, N. Oliverson, J.Mikolajewska, M.Mikolajewski, R.Stencel and C.Anderson  
1991 Astron. Journal 101, pp. 637-645.
13. "What do observations of giant and supergiant stars tell us about chromospheric and coronal heating in late type stars?"  
M. Cuntz and R. Stencel (invited review)  
1991 in *Mechanisms of Chromospheric and Coronal Heating*,  
eds. P.Ulmschneider, E.Priest and R.Rosner, (Springer-Verlag; Berlin), pp. 206-221.
14. "S Persei: Optical, UV and Water Maser Variations - 1984 to 1990"  
I.Little-Marenin, P.Benson, M.McConahay, R.Cadmus, R.Stencel and K.Eriksson  
1991 Astron. Astrophys. 249, 465..
15. "On the Interaction between Gas and Dust in Late-type Stellar Atmospheres and Winds"  
K.MacGregor and R.Stencel  
1991 in *Seventh Cool Stars Workshop*,  
eds. J.Bookbinder and M.Giampapa, ASP Conf. Series Vol.26, p.484.
16. "IUE and ROSAT Survey Observations of Symbiotic Stars"  
R.Stencel, E.Brugel, S.Kenyon, K.Bickert, T.Fleming & J.Schmitt  
1991 in *Seventh Cool Stars Workshop*,  
eds. J.Bookbinder and M.Giampapa, ASP Conf. Series Vol.26, p.46.
17. "A New Paradigm for Stellar Evolution"  
M. Cuntz and R. Stencel (invited paper)  
1991 at the Amsterdam Workshop on the Evolution of High Mass Stars"  
ed. C.deJager (Kluwer: Dordrecht).

#### PAPERS IN PREPARATION:

1. "Mapping the UV Circumstellar Shells of Red Giant and Supergiant Stars"  
R.Stencel, P.Judge and K.Carpenter  
1993 Astrophys. Journal, in preparation.
2. "IUE and ROSAT Survey Observations of CH Cyg, R Aqr and AG Dra"  
R.Viotti, et al. (incl. R.Stencel)  
1993, in preparation for Astron.Astrophys.
3. "Multiwavelength Observations of AG Draconis"  
R.Stencel et al.  
1993, in preparation for Astrophys.Journal.